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GROUP

# CANADIAN PATENT

LINER EXPANDER

Joe C. Stall, Tulsa, Oklahoma, U.S.A.

Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

FILED

PRIORITY DATE

No. OF CLAIMS

#### LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing ; or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 25 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The first-stage die provides a gross deformation of the liner so that it is expanded outwardly against the wall of the casing. The second-stage die then passes through the liner and performs the final expansion to smooth the inner surface of the liner and to provide more even contact between the liner and the wall of the casing and effect a fluid-tight seal.

In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 23 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38m is the same as that of the shaft threads 18m, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

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Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49s are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

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The columns of the column element 45 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lô.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein  $P_{\mathbf{C}}$  is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with, a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member \$2\$ engages with the wall of the casing and prevents thimble \$1\$ from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

- 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against said liner by a substantially constant force.
- 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
- 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 4. The device of Claim 3 wherein said compression means comprises a differential screw connecting said spring member and said shaft.
- 1 5. The device of Claim 3 wherein said stop means comprises a 2 sleeve-like element connected to said movable bearing plate member and slidably positioned on said shaft and a member connected to said shaft to 3 4 limit the travel of said sleeve-like element.
- ı 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
- 1 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted 2 3 on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said 7 arm members outwardly from said shaft; a plurality of slender columns, each 8 having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, 9 each slidably positioned on said shaft and contacting opposite ends of said 10 columns; limiting sleeves attached to each of said bearing plate members 11 12 and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply 13 a buckling load to said columns; said shoulder being engageable with the 14 limiting sleeve connected to said lower bearing plate member, whereby the 15 16 axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members . 17 outwardly with a substantially constant force. 18

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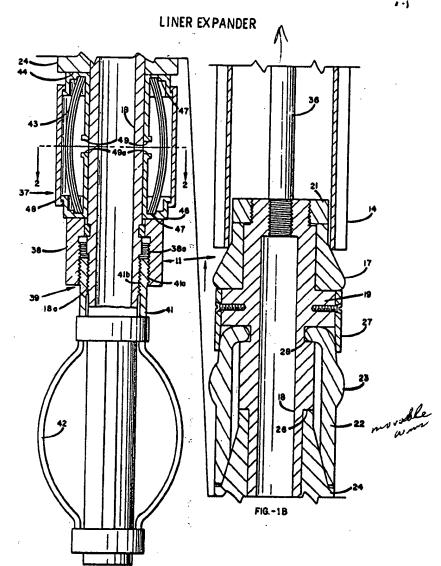
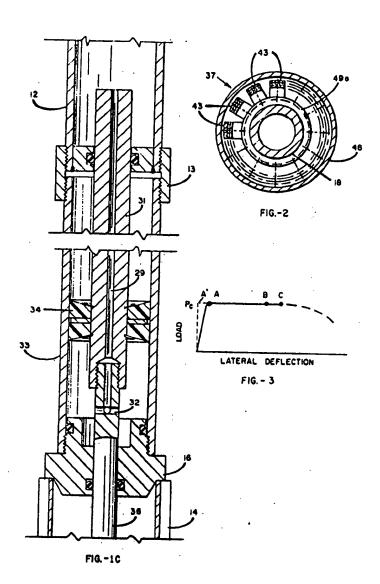


FIG.-1A



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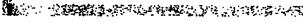
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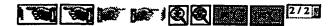
3. The fevelor of Claim 2 shared, said scartant force spring number comprises a planning of columns disposed across said shaft, a start tearing plate seaher, such of said bearing plate seaher and a second bearing plate scales, such of said bearing plate scales of said columns, an least one of said bearing plate members being speedly suite of said columns, an least one of said bearing plate members thing sevenly puritiesed on said starts and being in contact with said come member, step member along said starts on limit the adjal triveal of said memble bearing plate member along said starts, and compression member for said starts as a start of a charties in said columns.

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- . A. The device of Claim 3 wherein endd congression grows comprises a differential sprov consening make againg master and said shaft.
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- 7. A device for installing on expended soluble lies to a constitution comprises a systematical short olseant, on expending the souter annoted on mid short, and the ensers comprising a plantity of any medical distance control elements under an entering installing annotes the simple of each short and budge plustably positioned on sold about between entd short and made are medical to unput sold one modern objects to sign and one numbers objectly from sold shorts a plurality of alaming columns, each being a long recompositer occon-service, and disposed elements entitled where sold shorts as upper bearing plate members and a lower bearing plate members, each alterity positioned on sold shorts and contenting plate members and alterity positions are sold shorts a shoulder made on sold shorts a differential across alternate extending and shoulder made on small shorts a fifth-tential across alternate examinating sold shoulder being assessments the limition sleaves assessed to said leave being assessment, whereat the arial traval of and bearing plate anabors in limiting their bushing look to eath are anabors to urga said and anabors to urga said and anabors autourally state a substantiality counters across to urga said and aparters actually state a substantiality counters across to urga said and aparters actually state a substantiality counters across and and accounter state of the urga said and accounter statements.





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As abject of the process invention is a forces for applying a constant force to an expending also or other similar expension so that a proscisoted maximum force to ascreta against a work place. Souther object is an improved expending tool for installing metallic linear in a conduct, which expending tool our apply so greater them a predictareized force to the linear being installed in the conduct. Still number object of the invention in an economical and contily fabricated assessmit force spring device. A further object in a regard, assy-to-operate expending tool coplaying such a opting device. There and other chipsets of the invention will become apparent by

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My interior will be better understood by reference to the following description and the securetying drawings wherein:

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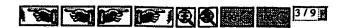
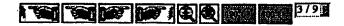


Figure 2 is a sectional where of the apparatus of Figure 1A taken at line 2.2: and

Figure 5 is a typical plot of applied lock versus beflection for the constant force muring device of the Levention.

Referring to the averings, Figure 15 is the botton portion of a liner supersing tool for one in installing a scholle liner in a well, while Figure 19 illustrates the static section of each a tool and Figure 20 represents the upper covision of the tool. The expending tool 11 is obtained to vicesteri well taking 15 by assaing 15 and, typinality, may be invered from the section the taking 16 by assaing (not shown) to a point in the secting at which 15 is easiered to invisit a metallic liner. Before immerting the tool into the well, on alongsted varifically corrugated liner 16 their order from mild stool, or other suitable malianhic meterial, to placed on the tool. The convergetod liner is seemed in position by antient at its upper and with a cylindrical shoulder number 16 and, at the lower and by contact with a first-stage expanding die 17 in the form of a truncated circular soon which necesses as a first-stage expending die 17 in the form of a truncated circular soon which necesses as a first-stage expending die 17 in the form of a truncated circular soon which necesses as a first-stage expending die 16 in this second to a contrally located, observed syldatrical hollor shorts 16 which forms a pertine of the long of the tool. As shown, the expending die 17 is half in place between a lawy shoulder 19 and collar 13 threaded acts the short. A plurality of movedle are should surface of the margin pertines of the same the toy, are disposed in the form of a quinting new arrangement of the source of the member the shorts to accordance to allow the cutterfuly dependent. The serious of the arms of the source who as a second-stag symmetry at another the state accrease of the arms and sore them cutterfuly. Mynataspoonly, the facile serface of the arms 22 and the outside surface of expending number 25 forms acting accordance to the member 26 which moves received to accordance of the arms 22 and the outside surface of expending sections of the same the of the member 26 which moves received.





uril) it contains sheater 25 provided on the sheft. As number 26 noves in a documently direction orns 52 fall imparily towers the sheft. The expending sizes 22 are held in place as the sheft by collect 27 and circular grooms 20 provided on the shaft.

The expecting tent, comprising the fivet-stage die sed the counterriage die is dreen through the liner to expect to the place in the content. The first-stage die prevides a gross deformation of the liner so that it is expected outworthy against the well of the content. The second-stage die then passes through the liner and performs the final expectes to except the liner surface of the liner and to worths more even content brivess the liner and the well of the content and effect a final-tight seed.

In operation, the liner setting tool is assembled at the surface, as and a glass thoth saturated with a revisions material any be the corrugated take to form the liner. The assembly is lovered all as the leastion at which the lines is to be set. A signis, such are does the well taking and flows through 29 provided in goliabed and \$1, through parts 52 and into equined to the upper and of the aboulder 16. Upon the opplication of to the opinion, the pistes 34 second to political red 31 moved or 33. As shows, rot 36 consects political rot 31 and shaft ed the Right-stage expending the 17. Then the piston A uph the splinter 33 the expending die 17 und the seconders specially into the entropeted liner th and "iron sub" Some in the liner, so that the expended liner may contect the all of the casing in which it is being installed. Positioned on the the expending member th is a constant tirres spring number 27 which to mys the expecting number against the explaining some 22 with a setant force. The force exarted against the est mobble baing steam, the force presentated through the are senters to the a during will be substanticily assertant on that aither phisting to center or resture of the center is precluded. Of so

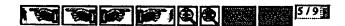


enticina, vin A Neithernational Caranto Calabra, i respectivistative (s. 1211)



Zarone between the tool and the inner and the presence emerted defined the secing are excitationd at presentantical end safe levels. The comment force spring member assumes that the contact pressure between the liner forming pertion 25 of the same 22 is great enough to provide the Sorinal deformation of the sading, while preventing demons to the cealing or to the tool.

The qualitatic forces spring standar 77 is allightly spinned on the shall like between the expecting standar 38 and a splination) lover shoulder sucher 38 forming a portion of a differential server almost 39 which brimming the localing on spring number 37 to shall makes 18. The differential cover almost comprises that's number 18 on the outside of which are not note threads 18a, the lower shoulder number 18 on the outside of which are not note threads 18a, the lower shoulder number 18 provided with female threads 35a and threads, respectively, to suppose with threads the and the shoulder and the instite, respectively, to suppose with threads on the shall and the shoulder. The two code of threads are source, such as square, multiple opening, or done threads, to withertand very high loads and differ in pitch so that shoulder 35 is severed specify on the shall then the shall is revolved relative to thinkle \$1. The shoulder 36 is seemed to the shall is revolved relative to thinkle \$1. The shoulder 36 is seemed to the shall it is repliced to the chart if it only these to relate on the shall. Finally attached to the lower out of the thinkle is a friction sector, such no box thrings \$2, a hydramically equated friction pas, or other such device for friedlocally magning with the isolds will of the samplet to eccess the thinkle squared twistion with respect to the shall of the shall to eccess the thinkle squared hand threads, and the pitch, or load, or other such devices of the charlier number \$25, with the pitch rolle hing above to make. It had the shall be sha





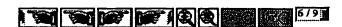
Constant force spring element II comprises united absents \$5, elementageously seprimiting of a plurality of alongsted solume dispensed around shorts.

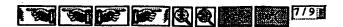
18. Upper bearing plate number in in to content with the alper ands of the solume and is ultimbly positioned so shall 18 to treated the force of the spring longitudinally against the botton and of expenses seeder 24. Lever bearing plate number in contents the lover ands of the column and is sorted against the shall by longitudinal nervouse of least shoulder 39 or a result of revolving differential serve almost 39. Green's NT are provided in seals of the bearing plates, to from an upper rate and a lever rate, into which the costs of the column are inserted. These growes my be shaped to content with the shape of the column such if desired. A cover 18 may be employed to amplife freeign antier from the spring Secteding and to protect the spring.

A notes for limiting the disflortion of the column is required.

Although the oclumn element furetions in a bushled contrion, application of excentive accurrently load thereto would come total failure or repture of the volume. Therefore, a pair of stope to see by see provided for this purpose. As shows, the stope are rigidly commuted he the bearing plates, and, in effect comprise upper see lover limiting classes positioned on the shaft to alide longitudinally thereon. The under of the stope my save lowers, or see, from, each other me the load in the outing number vertes. Lover slaves by it presented from meeting damp by larger absoluter vertes. Lover slaves by its prevented from meeting damp by larger absolutes 38 nonnected to the about 18. Ensurer, the spacing between the main in much as to limit the longitudinal freezi of the bearing plate meeters on they more together to prevent permanent deformation of the column almosts 57. Thricon alternative manus for preventing assage to the column almosts my also be explayed. For example, plate or rings accusted on the start my serve as stope, or the open 48 provides with switchile consecutors my be explayed for this purpose to limit longitudinal analyer lateral seriestics of columns.

The column of the calum nigrent h3 may be narranged around the grant 1.8, which as shown have turns a purbles of the body of the spring device, with make of the columns fithest in the recess hy. The solubles may be

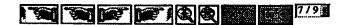


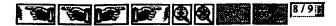


Fitted closely together as abore, or may be spaced around the race, with non-rators used between them to meiatods the desired spacing. The number of solutes suplayed will depose upon column observations and the metastate of construction. For example, the standardees ratio of the column may be whilst widely, and the column make may be recent, flet, fixed or hinged. The preservation is a tide, element calema with received axis, free to solve within the races shaped to the commission of the solves said. Naturals thick may be satisfactorily employed for the bolimes are certain and low alloy elements, chromical engages been alique, such as plausible bronze, baryline support, the high mishel alloys and other similar materials providing satisfactory sections, various appear have alique, such anterials providing astisfactory sections, such mishel alloys and other similar wideal columns are of long rectamples cross-contion, with the midth bring greater than the talchman, and arranged so that the wider race of the asymmetic is anomal to the nimeters of the others. Thus, with carticisate consensation loading, the volume tackle, and hend shoult the next thring the loads committee of inertia, e.g., publishing says from the short 18.

For example, a group of columns 0.167-tack thick by 0.438-fack wife by 10.626-inches long, with the ands rounded, were febrioated from A.I.S.I. 4350 start, granulat and draws at 575°F. Buth column was found to regular a critical suspension loading of 350 pounds in order to backle the extent. mitting, the columns were from to have a very first spring characteristie, as shown in Figure 3, wherein Pa is the critical backing load and point tie the look and deflevision at which the streep in the excepts filters of the delarm exceed the yield point of the untertal. Mecrotically, the shope of this spring obstantaristic ourse is described by ourse CATAIC. Astmally, this curve is described by GAN due to friction in the system. Foliate A and 3 ut typical serving limits, which, of course, may be veried according to the application for which the spring to designed. For example, where a large of floring system are not motivipated, a working stress just below the yield point may be used, while with a great number of floorers, the working stress may be held to have then the sufference limit of the selected of t In the above-mentioned tests, the internal deflection was blacked to

-7-





approximately one link, at which the longitudinal deflection was approximately D. 857 inches. From were deflection to the assisted deflection, the \$50-pound loading was found to be substantially constant.

In enother test a spring device was hull, as done, employing 20 column, each having a critical bushling look of 1250 younds. The internal deficient was limited between 0 and about 1.00 lankes by exprendically post-bloning the steps. Open compressional looking, the spring element buckled at entertainly 25,000 younds and from a longitudinal defication of 0.00 indeed (maching) to stout 0.15 lankes the look remained substantially at 25,000 younds.

Of course, in contening a spring elevant on above 16 in advantagements obtain the greatest possible value of longitudinal defluctions for operation values of longest defluction and critical bushing lond, while unintesting the atmost lovel to the columns at a case lovel. The greatered columns, therefore, are laminated, as shown in Figures 12 and 2, with unitiple flat members unities us asset below as above to Figures 12 and 2, with unitiple flat members unities us asset columns.

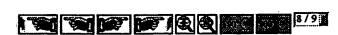
Do the operation of the shows expecting tool for setting a liner in wall sending, the made-up tool is lowered take the sell us sentioned above, with the area 22 in the retreated position. Were the tool is on the desired level, the sain testing is revolved. The friction matter by regages with the wall of the senting and presents thinkin \$1 from revolving. With several revolutions of the twing, lower shoulder 30 is moved numerity by differential neares 39 to bush to spring almost 37 which has a predeterminal critical bushing level. Sain last in transmitted appearing against the lower and of expender 26, and its topored surface is ongaged with the tapared surface on the inside of the crew 22 to args the term outstardly with a substantially constant force proportional to the critical bushing loss of the spring almost. Panesquarily, the expending tool is passed through the liner to expend it in the secting in the sector described breatheriors.

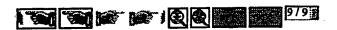
the foregring coveription of a preferred embetiment of my investion.

Las been given for the purpose of complification. It will be understood that
rection medicionalisms in the details of amortunation will become experient to

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the artises from the description, and, as such, these fall within the spirit and source of or invention.



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